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reSEARCH
THAT MATTERS

5: **Taking Measure**

Does Modern Math
Education Add Up?

College of Education

Dear Colleagues:

Last fall, Judy Mitchell, Dean of Washington State University's College of Education, and I convened a group of 26 of the state's superintendents at a conference sponsored by Microsoft. We asked, "If you are to be successful with the children we serve, what would our colleges of education be doing?"

"Helping us with math achievement," they said.

"Training more math teachers."

"Helping us explain the "math wars" to parents, board members, and our own teachers."

We were already working on these issues — but as a result of that conversation, we stepped up our efforts.

School districts face problems almost daily, as newspapers quote parents angered over their children's low math results on the Washington Assessment of Student Learning. The news stories describe confused students who face conflicting teaching methods from one grade to the next and different curricula as they move from one school to another. They cite business leaders who worry that more American jobs will be outsourced if the next generation can't master critical problem-solving and reasoning skills.

It's also true that teachers are frustrated. They are being tasked with presenting harder subject matter to an increasingly diverse student population, even as legislative mandates require teachers to bring students — ALL students, including the state's lowest achievers — up to higher academic standards in mathematics.

Every spring, we receive inquiries about the availability of graduates from our teacher education program. Who, school districts ask, will be graduating in math education? Do the graduates already have job offers? The answer is probably yes — even if it is January and graduation is not until June. Although we are working hard to prepare more teachers in mathematics education, it's hard to recruit students with strong math backgrounds into teaching and hard to retain them, with the lure of higher-paying jobs in technology, science, engineering, finance — fields in the wired world that thrive on out-of-the-box mathematical thinking. The applicant pool for math teachers is far too slim to address the state's needs.

To make matters worse, nationally, about a fifth of public high school math teachers lack full certification in their field, especially those in low-income urban schools. Some neither minored nor majored in math. Even veteran certified teachers aren't receiving adequate professional development to help their students not only master core math concepts and principles, but make sense of them using analytical, logical, and creative problem-solving skills. It is also true that youth in the United States have performed poorly in comparison with their international peers in math. Ironically, international comparisons reveal that students in top-performing countries are often assigned fewer math problems per lesson but explore them more deeply than is typical in U.S. classrooms.

How can our K-12 students improve their understanding of math given these circumstances?

The UW College of Education is addressing these issues in its inquiry-based math education program. Our faculty are working to ensure that elementary teachers graduating from our program have a deeper understanding of the math they will be required to teach and that secondary teachers are prepared to help students who excel in math, as well as those who find it difficult. Our faculty are preparing new Ph.D.s to fill the need for more professors in our colleges and universities at the same time that they work with practicing teachers to explore new curricula and instructional methods.

Our faculty have analyzed thousands of student-teacher exchanges to see what genuine mathematical understanding looks like, how it can be monitored and assessed. They have gone into workplaces and households to see whether the math taught in schools translates into the daily problem-solving of children and adults.

The faculty moved math methods courses out of classrooms at the university and into local schools. Further, we follow our teacher education students through their student teaching and into their first two years in classrooms so that we can help them negotiate very complex classrooms while they gain critical formative experiences.

Our faculty serve not only those entering the teaching profession, but also currently practicing educators. Based on school and district needs, they have built intensive workshops and developed in-school coaching and collaboration programs to help teachers and principals ensure that their students really understand the math they are expected to know.

These inquiry-based approaches are under intense scrutiny by policymakers and educational administrators. The pressures to improve student achievement have fueled the “math wars” — noisy, heated arguments between math “reformists” and “traditionalists.” As my colleague Mark Windschitl describes the debate, simplistic stereotypes paint the first group as “fuzzy math” advocates, the second as rote-and-drill “control freaks.”

These “math wars” are divisive and counterproductive. It’s time, as my colleagues argue within these pages, to move beyond angry rhetoric, to pose important questions and hold productive discussions that are focused on student learning.

Good teaching, UW faculty research shows, is not an either-or, one-size-fits-all matter. In the best math classrooms, teachers adapt a variety of teaching methods to maximize student learning, knowing one child may learn best by listening and memorizing, another by talking and visualizing. These teachers develop in their students a love of mathematics as a system of deeply linked ideas. The teachers pose questions, push engagement, enable students to make critical connections.

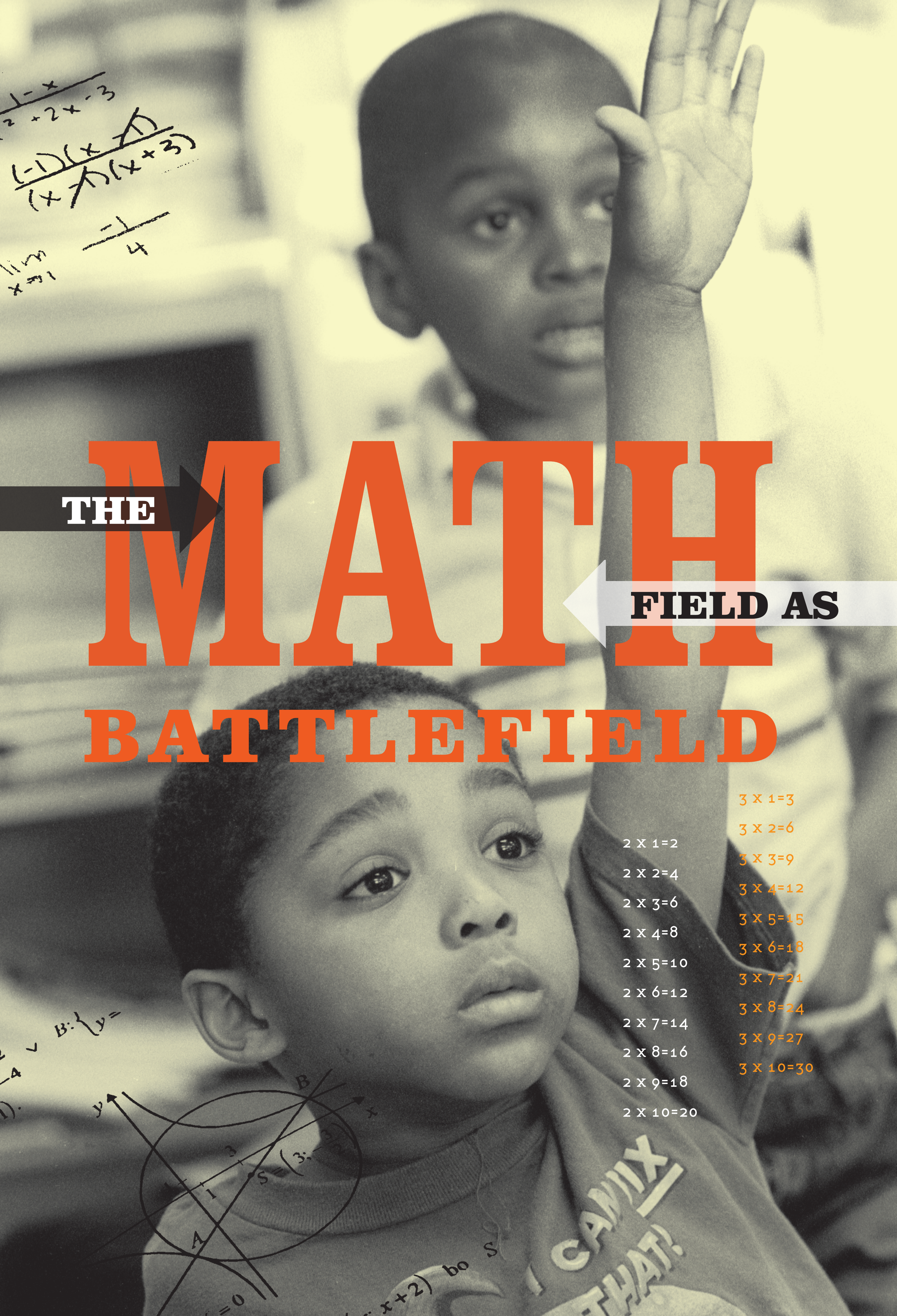
Their students know that 12x3=36. And they also know why.

It’s difficult work, and it requires sophisticated teaching skills. Our faculty, along with our WSU colleagues, are working hard to improve math instruction, right along side our school district partners. We believe that together we can be counted on to make a difference.

Patricia A. Wasley

Patricia A. Wasley, Dean and Professor

THE MATH FIELD AS BATTLEFIELD



The gloves have come off in the “Math Wars”

in Washington State. In one corner are the traditionalists, protectors of “real” math, true math. They’ll fight to the end for tried-and-true facts, principles and procedures. When they look across the ring, they see opponents who they believe have lost their way — new-age teachers who indulge students, allow noisy free-for-alls in the classroom, engage in “fuzzy” math, press students to draw pictures, play games and “discover” why 3x4=12.

In the other corner are the upstarts, the reformists, the math educators who strive for “deep understanding” in the classroom. When they look across the ring, they believe they see rote-and-drill advocates who muzzle students, never make them think. They see “control freaks” who stand in front of a class making mathematical pronouncements for students to repeat, memorize. Their classrooms are lifeless, their students miserable as they work through dull, repetitive, meaningless exercises.

Such simplistic stereotypes dominate today’s divisive knock-down drag-outs over math and science education. “Rarely does anyone come into the debate saying ‘Oh, I‘m a little of both.’ People self-identify with one side or the other, “ says UW associate professor Mark Windschitl, who teaches science education and serves as chair of curriculum and instruction in the College of Education.

In truth, he points out, the best traditionalists stand in front of the class, make math fascinating through storytelling and clear explanations of concepts, give lots of examples and engage student attention.

The best reformists facilitate complex mathematical thinking. They elicit students’ ideas to find out what they already know and build instruction on the findings. They ensure students not only engage in mathematical activities that lead to mathematical procedures, but know when to put those procedures into action to solve problems.

Both sides want students of all backgrounds and abilities to improve their mathematics skills, and both agree that math teachers in this state need extensive subject matter knowledge to do their job.

So why have people who care so deeply about student success turned the math field into a battlefield?

The question intrigues Windschitl. He has studied the language and images used by both camps in the virulent math and science battles — camps that stake out their positions daily on editorial pages, Internet sites, blogs, sound-offs. “It’s hard to overestimate how nasty this debate is nationally,” says Windschitl.

Words used by traditionalists to describe reformist methods include “ineffective, inefficient, cumbersome.” Words used by reformists for their counterparts’ methods include “rigid, authoritarian, outmoded.”

What makes it so hard for the two camps to talk are deeply held underlying values and beliefs. Many educators say the wars have as much to do with politics as they do with education. Even discussions about a seemingly neutral topic such as student thinking rarely play out in a productive way.

“To traditionalists, student thinking means comprehending, integrating, applying knowledge — specifically, how the teacher comprehends, integrates, and applies knowledge. The students’ job is to figure out how the teacher made the connection, how to reconstruct the teacher’s thinking, and how to memorize it,” says Windschitl.

“To reformists, thinking means sense-making. It means students going beyond the information given by the teacher and making connections for themselves.”

“In the one view, knowledge is acquired from teachers. In the other, it is learned via sense-making by one’s self.”

"It's hard to overestimate

Morris hated raking leaves. There were two trees that he hated the most, because they always were dropping leaves. One day he decided to count how many red and yellow leaves dropped from the trees every hour. In the first hour there were 8 red leaves and 8 yellow leaves on the ground. In the second hour there were 12 yellow leaves and 15 red leaves on the ground. In the third hour he counted 15 yellow leaves and 16 red leaves on the ground. In the fourth hour there were 19 yellow leaves and 23 red leaves on the ground. Then at the end of the fifth hour he found 22 yellow leaves and 24 red leaves on the ground. If the leaves kept dropping at the same rate, how many hours would it take

Both camps point to the low scores on the Washington Assessment of Student Learning (WASL) math test as proof that their opponents' methods are not working. Is reform math curricula hurting WASL performance? Or is it the rigidity of traditionalist teaching that leaves all but high-level students in the math-track dust? "The WASL is like holding up a mirror to ourselves right now," says Windschitl.

Low student performance may be reflecting the field's lack of consensus on what matters in mathematics.

The high-stakes test, tied to high-school graduation, is one force behind the venting. Another is the "gate-keeping" role of mathematics. Students who don't take advanced high-school math head down a different path than their college-bound counterparts, whose math track can lead to high-paying jobs in science, technology, and engineering. Is this the education everyone, under new legislative mandates, should be getting?

For students, the warring ideologies have too often resulted in a mishmash of teaching styles. While moves are afoot to adopt more consistent math curricula statewide, many districts remain a checkerboard of reform and traditionalist methods. Some schools vary grade to grade.

That can turn campuses into their own battlegrounds. Windschitl cites the example of a high school where the traditional vs. reform argument was so heated that administrators had to cancel all department meetings.

In all the noise, some important voices are drowned out, says Windschitl. And it may be the quietest ones that need to be heard, the voices of teachers who shy away from divisive words and concentrate on teaching.

They're the teachers who don't separate curricula into enemy camps, don't buy into either/or thinking, but assimilate the best ideas from both methods to tailor their teaching to individual student's needs. They're the teachers who know each child learns differently from every other child.

"Most good teachers use both active learning strategies and direct instruction, group work and seatwork, scripted exercises and individual student investigations," says Windschitl. "They want students to make sense of both the procedures and the underlying mathematical concepts."

Their success advocates for a lower-volume, more reasoned discussion of mathematics education, one that addresses shared goals for student learning and a shared understanding that there are many ways to teach. Amid that variety, however, students need to experience coherence from one class to the next.

Can a measured discussion happen amid such rancor? Are warring camps ready to put down their rhetorical weapons and enter peace negotiations?

It's a hard call. "A change in rhetoric is the only way to move the conversation off the battlefield and onto productive ground," says Windschitl. "The only thing you can do is start a dialogue and that means not talking ideology, not using straw men, not using stereotypes. It means trying to understand the other person's point of view."

With sides so firmly entrenched, it could fall on the next generation of K-12 teachers to broker a truce. At the UW College of Education, students are expected to initiate these dialogues when they take inquiry-based math methods out into schools, says Windschitl.

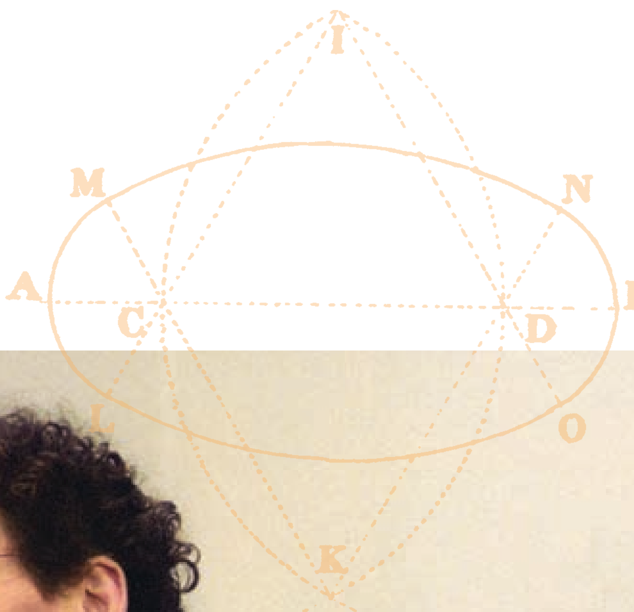
how nasty this debate is nationally."

UW ASSOCIATE PROFESSOR MARK WINDSCHITL

"We teach our students not to just become teachers, but to become teacher leaders. We are not preparing them to be spectators in this debate."

FOR MORE DETAIL ON WINDSCHITL'S ANALYSIS OF THE IDEOLOGICAL WARS SEE:

Windschitl, M. (2006). "Why we can't talk to one another about science education reform," *Phi Delta Kappan*, January, 349-355.



PRESSING

FOR MATHEMATICAL UNDERSTANDING

The problem, on its surface, is simple:

A toy is hidden in one of two cakes. One cake is a circle, cut into fourths. The other is a rectangle, cut into sixths. Students must choose the cake that gives them the best chance of finding the toy.

Some choose the rectangle. Why? Because “most toys come in square boxes.”

Logical enough, if you apply a child’s real-life experience to a theoretical situation. Teachers who mark the rectangle answer incorrect, who move onto the next problem without asking “Why?” may miss the thinking behind the child’s solution to the problem. They may believe that their students did not “get” probability, and the answer is just to reteach says Elham Kazemi, associate professor at the UW‘s College of Education.

“The question is what we do with errors,” says Kazemi. “Teachers can use them to reconceptualize a problem, explore contradictions in student understanding, and try out alternative instructional strategies.”

In the real world, Kazemi points out, people study errors to avoid the same mistakes. Football coaches study bad plays; diving coaches study splash patterns; analysts study the processes that led to flaws in a financial report.

Kazemi has spent countless hours listening to student-teacher exchanges in classrooms, recording dialogues and analyzing them to see how successful teachers develop children’s mathematical thinking. Her research shows that teachers who press students with strategic questions and carefully monitor their answers can move pupils to genuine mathematical argument and reasoning, even within elementary school classrooms. However, Kazemi notes that such instruction is not yet the norm.

“I wouldn’t say that the quality of mathematics instruction is universally high. We still have a long way to go,” says Kazemi. “The good news is that there now exists an array of professional resources to help.”

With a team of colleagues at the University of Washington collectively known as the *Mathematics Education Project*, Kazemi is working to build capacity to support excellent mathematics instruction in elementary and middle schools. Partially funded by a grant from the National Science Foundation, the project’s goal is to help systems support the professional education of teachers, teacher educators, and administrators and help them effectively engage with families.

Research by Kazemi and others has shown that well-organized, long-term professional development is needed to support teachers in creating the ambitious instructional practices that will allow all students to learn. The goals for the *Mathematics Education Project* grew out of the team’s understanding of the challenges schools and districts face in creating coherent plans for elementary mathematics professional development. The project has identified resources in elementary mathematics education to deepen teachers’ content knowledge, help them elicit and interpret student thinking, and advance children’s thinking through instruction. Resources are also identified to help administrators and parents understand their key roles in supporting children’s mathematics learning. Because using these new materials is complex, members of the project work with districts and schools to develop coherent implementation plans.

“We still see too many districts adopting a one-shot approach to professional education,” says Kazemi. “In the *Mathematics Education Project*, we’re committed to helping schools and districts learn what these resources offer to create a long-term plan to engage teachers and the broader system in substantive work on their own teaching.”

At the core of the project’s work with teachers, teacher educators, administrators and families is the view that teachers should use a deep understanding of students’ mathematical thinking as well as a clear understanding of mathematical content to guide instruction. School leaders learn how particular resources can support knowledge and skill building. Educators, leaders, and families come to appreciate how students’ thinking develops as they explore students’ understandings and, especially, their misunderstandings. The resources recommended by the *Mathematics Education Project* reflect the goals to deepen mathematical understanding and bring to the surface the significant work that teachers do when they anticipate, elicit, and advance students’ mathematical knowledge.

“When you get kids to show you what they’re capable of, you are amazed,” says Kazemi.

"As teachers talk with students, they need to press to find out what, exactly, they know. What students know should determine what the teacher does next, what kind of conversations the teacher prompts, and what comes next in the learning trajectory."

UW ASSOCIATE PROFESSOR ELHAM KAZEMI

One student may add 28 + 34 with traditional column carry-over. Another adds 2 to 28 and subtracts 2 from 34 before adding the two results. A third student adds 8 and 4 to make 12, then 12 and 30 to make 42, and 20 more to make 62. In an effective classroom, all those solutions are studied, the links between them established, and the connection made to larger mathematical concepts (such as place value, the properties of addition, and developing generalized strategies).

"As teachers talk with students, they need to press to find out what, exactly, they know. What students know should determine what the teacher does next, what kind of conversations the teacher prompts, and what comes next in the learning trajectory," says Kazemi. "It's important to understand the kinds of connections that students make between ideas. Mathematics is a body of knowledge that makes sense because of the relationships."

Eliciting children's mathematical thinking is a skill Kazemi also emphasizes in her math methods courses for teachers-in-training. To provide her student teachers with first-hand experience exploring children's ideas, Kazemi has taken her methods classes out into elementary schools partnering with UW's Teacher Education Program.

In one first-grade classroom, Kazemi had her UW students interview first-grade students in conjunction with a district-mandated assessment of counting and computational skills. After the interviews were completed, she and her students gathered to interpret and score the assessment and interview data, using the very framework the classroom teacher was using through the school's professional development, and then collated the results across the whole class to share with the teacher.

"It became apparent, through our analysis of the whole class, that the first-graders were ready to be challenged to move their problem solving approaches beyond their fundamental counting strategies," says Kazemi. "We also noted by compiling our interview data that students were very comfortable with a particular kind of word problem and struggled with others."

The classroom teacher benefited from this opportunity for each of her first graders to be interviewed by an adult, and she left the conference with Kazemi and her students strategizing the next set of problems she would pose to her class. The student teachers experienced the direct link between what they were learning in their methods class and the work they would be engaged in as teachers.

For Kazemi, these are crucial steps in preventing these first graders from sharing the fate of more than 40 percent of the state's tenth graders in 2007 who failed the math portion of the Washington Assessment of Student Learning (WASL). "When we see such high failure, it's not as simple as 'The kids don't get it,' " says Kazemi. "When kids are getting wrong answers on a whole slew of problems, we should be asking, 'What is it that they aren't understanding? What skills do they have? What do we need to build? and What does that say about our instruction?'"

FOR MORE INFORMATION ABOUT THE RESOURCES USED IN THE MATHEMATICS EDUCATION PROJECT SEE:

Kazemi, E. (2007). Supporting elementary mathematics through long-term professional education. *Curriculum in Context*, 34, 10-12.

depts.washington.edu/matheduc

FOR MORE INFORMATION ON DR. KAZEMI'S WORK ON STUDENT THINKING SEE:

Kazemi, E. (2002). Exploring test performance in mathematics: The questions children's answers raise. *Journal of Mathematical Behavior*, 21, 203-224.

Kazemi, E. & Franke, M.L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, 7, 203-235.


Alvin is 24 yrs. old
24=2 Bobs
24÷2=12
Bob is 12
12=2 Carlas
12÷2=6
Alvin is 24 yrs. old
Bob is 12 yrs. old
Carla is 6 yrs. old

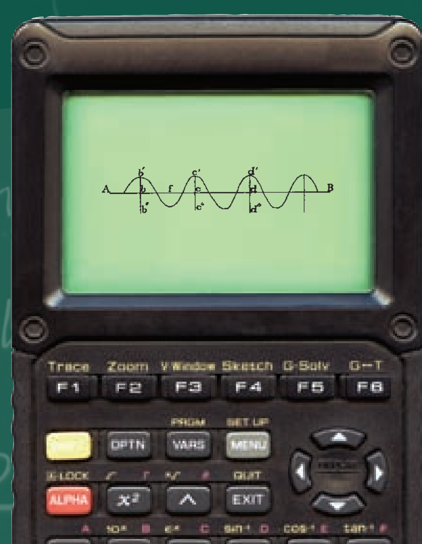
OUTSIDE THE CLASSROOM:

Where's the Math?

What happens when school math ranges out into the real world?

What if it never makes it that far?

What if it's permanently stuck inside the United States classroom, in textbooks and drills, weekly quizzes and standardized tests?



At the center of the current debate about math instruction is the question of what basic mathematics students really need. Is there a difference between the math everyone needs and the math needed by those who go into math intensive fields?

These are questions Reed Stevens, associate professor in the UW College of Education, has been considering for some time. “As a student, I heard, ‘Oh, you’ll learn all this stuff and then you’ll apply it some time later,’” says Stevens. “I took it for granted that was true.”

Was it? Stevens, who has an undergraduate degree in mathematics and a Ph.D. in cognition and development, decided to investigate by examining the evidence for such claims.

He spent months inside the offices of professionals, following their daily work and projects. The professions he has studied include architecture, engineering, and science and are among those where we conventionally expect the most clear applications of school math. The architects, he discovered, worked problems out with visuals, not textbook algorithms. Engineers use mathematics, but much of that is embedded in their computational tools, and they too use forms of quantitative reasoning that looked very different from the activities of school math. It turned out that school math was a fairly rare species of activity outside of school.

“If you spend a month with architects, you’ll never once see them write an equation,” says Stevens.

The story was the same when he studied roadway engineers. “All the calculations were done on the computer,” says Stevens.

The professionals who actually do use school mathematical forms in daily practice are professional mathematicians. “They really do represent things mathematically in everyday life,” says Stevens, who taught higher mathematics at both high school and college levels. “They’re like poets who can hear poetry in everything.”

That poetry is apparently lost on the American Everyman and Everywoman. In a recent ethnographic study, Stevens and three UW graduate students spent months inside private households, documenting how families dealt with bills, mortgage refinances, kids’ college saving accounts, credit card debt. If there is one set of experiences where we’d expect to see school math in everyday life, it is in these consequential financial situations, but again, they saw little school-like math in action. “Almost to a person none of these people would take the school math, put it on a piece of paper and translate their situation through it,” says Stevens.

His team also collected all the financial offers that came through household mailboxes in a month: credit card offers, life insurance offers. “This deal, that deal. How do they choose?” says Stevens. “Mathematics education has not armed people to make those decisions. It could, and it should.”

Contrasts are stark between the real world and the traditional mathematics classroom. The school math routine is familiar: Mass-marketed textbooks progress topic by topic. Students are asked to solve problems under each topic: linear equations, quadratic equations, factoring. Teachers illustrate how to do it, then have all their students repeat the algorithm. Finally, there is the test, the mandated grade. Some students pass, some fail. Then it's onto the next unit.

The outside world doesn't operate that way, Stevens points out. There are no scores, just practical demands. Everyone does different tasks. There are divisions of labor. And, as unskilled jobs continue to disappear from the U.S. economy, there are increasing demands for problem-solving and critical-thinking skills in employees.

Is it practical to try to bring this outside world inside the classroom? One approach — hotly debated among mathematical reformists and traditionalists — is project-based math. Under this model, students might be tasked with restoring a Northwest salmon stream to health or designing a livable building for scientists in the Antarctic.

Ideally, working in groups, students pore over geometric forms on blueprints or design comparative salinity studies of river water. Guided by teachers, they debate mathematical ideas over weeks or months, then come up with original solutions for practical real-world problems.

Stevens weighed the pros and cons of project-based math after an in-depth look at one middle-school classroom. On the positive side, the projects engaged a wide range of students — not just the high-achievers on college math tracks. The projects also proved to even reluctant students that mathematics could be a useful tool.

But Stevens also witnessed how genuine opportunities for recognizing mathematical moments can get lost if teachers aren't there to catch and guide them, and how difficult it is for even the most well-intended instructors to tear away from traditional methods, such as worksheets and tests.

"It's important to ask 'Is this a real problem — or is it a cover story for [school] math as usual?'" says Stevens. "If students don't have the sense that it's real, if they think it's pretend, then it's just theater."

For reform practices such as project-based math to work, he argues, educators will have to accept wholesale, consistent, school-wide change, real change, not "theater." That's difficult, despite the fact that old methods have failed so many students on so many levels.

Even high achieving students are falling below international standards. In 2004, students in 11 out of 15 countries in the developed world scored higher than U.S. students in advanced mathematics. No country scored significantly lower.

At the same time, demand for real-world mathematical skills is increasing. Stevens wants to understand just what those demands are. Science and engineering occupations are expected to increase 70 percent by 2012, while others increase by only 15 percent. Will these high-skill jobs be outsourced to other countries? Can our math catch up in time?

"It's important to ask," says Stevens, "how much of the mathematics learned in school can be applied in the real world? Not the real world of astrophysics — the real world in which we all live, where every day we face decisions that mathematical tools and ideas might inform." It may be that the math we require in schools, or at least the way we often present it, is not the math we actually need.

FOR MORE INFORMATION ON STEVENS' SCHOOL AND WORKPLACE COMPARISONS SEE:

Stevens, R. (2000). Who counts what as math: Emergent and assigned mathematical problems in a project-based classroom. In J. Boaler (Ed.), *Multiple Perspectives on Mathematics Teaching and Learning*. Elsivier.

Stevens, R. (2000). Divisions of labor in school and in the workplace: Comparing computer and paper-supported activities across settings. *Journal of the Learning Sciences*, 9, 373-401

"If you spend a month with architects, you'll never once see them write an equation."

UW ASSOCIATE PROFESSOR REED STEVENS

CAMPUS IDEALS MEET CLASSRO

When student teachers enter urban classrooms ready to engage in big mathematical ideas, the challenges can be daunting. "Culture shock" is the term one UW student used after confronting the complex mix of classroom abilities, cultures, languages, personalities and demands.

Teachers-in-training at the UW College of Education — which incorporates real-world classroom immersion into math methods instruction — encounter low-achieving students who claim “I don’t do math” and high-achieving students who can successfully complete computations, but have no idea what they mean.

They find Muslim students who spend the first 15 minutes of a 50-minute class in prayer, and struggling English language learners who leave teachers wondering: “Should I modify the lesson for them? Is that fair? What do they already know? How do I find out?”

The UW students, many white and from suburban backgrounds, encounter immigrant children whose parents work three jobs to make ends meet, students of color who challenge them on issues of race, teens who don’t want to lose face in front of their friends by trying in school, and kids who have never seen a point to studying.

For Alayne Cartales, a recent graduate of the UW College of Education’s teacher education program, the ideals of campus met the realities of the 21st-century classroom when she was assigned to student-teach in a math classroom where almost

OM REALITIES

half the pupils were special-education students. Her job: to get them up to speed while keeping a handful of advanced students mathematically challenged. “I just tried to keep my head above water and reach as many kids as possible,” says Cartales.

These on-the-ground experiences are eye-opening, both for UW students and the faculty researchers who closely follow them into their first years as teachers. “When we’re at the university talking about teaching, there are many aspects of the classroom we can bring to life: lesson plans, activities, even student-teacher role play. But none of this does justice to the complexity, the particularity of students in an urban classroom,” says UW mathematics education professor Ilana Horn, whose research team intensively studies the gaps between academic theory and real educational practice.

Horn says would-be math teachers often come into UW classes expecting tips and tricks, not the complex concepts and practices instructors use in math education. “They think they can follow a recipe and magic will happen,” says Horn. “But good teaching is more about problem-solving than deploying some particular method.”

It’s a lesson brought home for math education students who, over the past two years, have spent part of their first quarter at the UW in a Puget Sound urban high school, observing in classrooms, studying lesson plans, debriefing with teachers about what happened in class and why, pairing up with high school students struggling with math.

“Students who go through this field-based methods class are much more humble about how hard teaching is,” says Horn. “We want to send student teachers out with the idea they have something to learn from any competent teacher out there.”

The UW students are typically high achievers who “got” math in school. They’re surprised to find students who don’t even know how to add fractions. “For them, it’s a shock to see the level of math these students are doing. They, themselves, got it at that age. They didn’t struggle. It’s a reality check,” says UW research assistant Sara Sunshine Campbell, who teaches math methods classes.

Many of the UW students were taught traditional college-prep math curricula in school. They memorized algorithms, worked step-by-step through curricula. In that one-track world, there was a single right answer to a problem, and one way to get there. Teachers lectured. Students memorized. “Slow learners” were assumed to be missing the logical skills needed to do higher math. “Fast learners” often arrived at answers without understanding the mathematical process that got them there. But who noticed?

In the urban classrooms where Horn and her students work, the UW students find that what worked for them does not necessarily work for struggling and disengaged students. Instead of

"I just tried to keep my head above water and reach as many kids as possible."

ALAYNE CARTALES, RECENT GRADUATE OF THE UW COLLEGE OF EDUCATION'S TEACHER EDUCATION PROGRAM

dumbing down curriculum, the teachers are learning methods to help students engage in important mathematical ideas — despite gaps in their prior learning. As they engage with challenging content, they can learn some of the math they may have not had opportunities to understand in their earlier education. To make this work, one student may need visuals to grasp mathematical concepts; another may do best with hands-on projects. Discussion and argument, not lecturing, may be the best way to challenge them mathematically.

These aren't the quiet classrooms most UW students remember from their childhoods — classrooms where pupils, sitting in neat rows of desks, kept their nose in a book, and where talking might be considered cheating. But, at a time when federal laws demand unilateral academic equity, these are classrooms that must open doors into mathematical understanding for diverse student populations. "The way math was taught in the past did not give all kids access. It wasn't fair, and that's why so many students didn't succeed," says Campbell.

Not all teachers agree. In their field assignments, UW students see teachers using reform-based methods as well as veteran teachers who believe that such changes might reduce the rigor of the traditional curriculum. Some of the veteran teachers frankly state that they don't believe in group work, "But go ahead and try it if you want to." High school students, too, sometimes balk at new methods. "Of course, they may give you push back," says Campbell. "You are asking them to do the thinking. Before, the teacher did all the thinking for them. You're asking them to do something harder, to do more work."

Even some math education students are initially skeptical of the inquiry-based approach to teaching. Alayne Cartales was one of them. "My understanding of this instructional approach when I started was that students didn't ever have to memorize or learn algorithms, they'd just create them themselves. I thought, 'That's baloney. They just have to memorize some stuff.'"

"Now I realize that students do have to memorize some algorithms, but besides just memorizing, they have to understand the mathematical concepts involved. People keep saying they want students to be critical thinkers. Well, first you have to make them think. They don't always have to think when they apply an algorithm."

The former computer programmer and mother of two, entered math education at the UW as a second career. Her own daughter struggled with math and told her that math didn't make sense, that it was just a bunch of numbers scattered over a page.

Cartales took up the challenge to make math more than a bunch of numbers for her students. "I want to help kids understand that math is not a terribly awful, scary thing, that it really does have some uses."

Meeting that challenge is a tall order amid the many demands of the urban classroom. But the rewards are gratifying. "I like listening to kids argue about a math concept, a math idea," says Cartales.

"If they understand it, then they can see places to apply it, places they can put it to use. They learn they really can problem-solve."

FOR MORE INFORMATION ON DR. HORN'S WORK IN HIGH SCHOOL CLASSROOMS SEE:

Horn, I. (2006, Spring). Teacher collaboration and ambitious teaching: Reflections on what matters. *New Horizons for Learning Online Journal*.

Horn, I.S. (2006, Winter). Lessons learned from detracked mathematics departments. *Theory into Practice, 45*(1), 72-81.

Horn, I.S. (2004, November). Why do students drop advanced mathematics? *Educational Leadership*, 61-64.

LEARNING ON

IN-SCHOOL SUPPORT FOR TEACHERS

How do teachers update their skills? It's a question easily overlooked in discussions of inquiry-based mathematics reform. Yet today's math teachers are tasked with not only closing the achievement gap in increasingly diverse classrooms, but, in many districts, making radical shifts in their teaching methods as they do so.

It's a tough assignment for math teachers long trained in traditional methods, with little or no exposure to math reform thinking. It's even tougher for those with minimal math training. In Washington State in 2000, 55 percent of math teachers had not majored in their field, up from 49 percent in 1994.

A typical band-aid solution is to send math teachers to a one or two-day professional development workshop on inquiry methods. What results is often a superficial understanding of how to apply these methods strategically. "Most workshops are completely insufficient for training and communicating these practices," says Ilana Horn, assistant professor of mathematics education at the UW, who works with practicing teachers as well as teachers-in-training.

"Inquiry methods are just tools, and they can be used well or used poorly. If they're used poorly, parents may rail, 'Why are you making the kids talk to each other in class? Why aren't they working math problems?' But when these methods are used well, they can be incredibly powerful."

To help teachers learn to dig for deeper mathematical understanding in the classroom, the UW College of Education combines intensive on-campus workshops, collaborative work with teachers, and on-site coaching in high-school classrooms. Much of this work has been supported by the National Science Foundation and the Carnegie Corporation of New York.

The collaboration between UW faculty and classroom teachers started in one urban high school where teachers were frustrated when 75-80 percent of their students received D's and F's in introductory math. Teachers decided it was time to update their teaching skills and find a curriculum that would engage struggling students. Partnering with a team led by Horn and UW math professor Jim King, the high school teachers revamped the math program, adopted a new interactive curriculum focused on problem-solving, and changed their methods of teaching. The UW team offers training and support to help implement the curriculum effectively, including graduate students in math education as in-school coaches.

One of those coaches is Nicole Davis, who teaches two ninth-grade mathematics classes in another project school, freeing up time for math teachers to meet, plan curriculum, discuss student needs and write group-worthy tasks that involve students in engaging but complex mathematical problems.

Davis and the other teachers also observe in one another's classrooms, team-teach, and fill in for one another during student conferences. It's a model of shared thinking and collaboration, she says. "We model in our learning the ways we want our students to learn: no one of us alone is as smart as all of us together."

Like their teachers, the high school students work together, debating central mathematical issues embedded in interesting questions: How can you predict the length of a shadow? How much would it cost — and how much time would it take — to trek 2,400 miles on the Overland Trail? Eventually even the most reluctant students weigh in. "Everyone has different mathematical abilities," says Horn. "If you have a place for that, if you allow kids to be smart, the kids start to value each other."

THE FRONT LINES:

An important part of the teachers' collaboration is reviewing student work. Traditionally, teachers review and assess student work in terms of an outcome: the grade. But careful review of student work can be a powerful professional development tool, says Horn.

The UW team visits classrooms, often with video cameras trained on students. Later, they screen clips for teachers in a "Video Club," posing questions: Were the students engaged? What was their understanding of the problem? "It's like video playback when you're training athletes," explains Horn. "You analyze the plays, then debrief."

By end of the first year of this collaboration, changes in the first partner school were dramatic. Students were engaged, and they were engaged in higher-level mathematical thinking. Passing rates in first-year math classes rose from 20 percent to 60 percent. By the second year of the project, the school almost doubled their WASL math pass rates for African American and low-income students. The success has been replicated in the second school, which saw its pass rates rise from 50 percent to 80 percent. The learning was also substantial for the math teachers, who describe the initial year of the collaboration as both the hardest and the best year they have spent in a classroom. "This is by far the most growth I've ever made as a professional," says one classroom veteran.

"The way we're doing this requires a big financial commitment, because teachers need time built into their schedules to meet and review student work," says Horn. "The question is, are districts — and the legislature who funds them — willing to invest in teachers this way?"

The cost may be large, she says, but the need is urgent, and the rewards are high. Just ask the students who now pass introductory math — and actually like it.

FOR MORE INFORMATION ON THIS COLLABORATION, PLEASE VISIT:

education.washington.edu/research/rtm_06/do_the_math.html#

education.washington.edu/areas/ci/profiles/horn.php

"No one of us alone is as smart as all of us together."

UW GRADUATE STUDENT NICOLE DAVIS, SCHOOL-BASED MATHEMATICS COACH

LOW TOLERANCE

HIGH EXPECTATIONS

Although they represent about only one percent of the overall student population, students with emotional and behavioral disorders (EBD) can command a good percentage of a teacher's — and principal's — attention. Some of the "troubled kids" act out, some mumble to themselves, some never say a word. They may be hyperactive, depressed, schizophrenic.

Their tolerance is minimal. Even though about a third have IQs over 100, they typically perform poorly in all academic subjects. Out in the real world, as adults, they struggle. "EBD kids' adult outcomes are the worst, partly because they don't get along with people very well," says UW professor Richard Neel, who researches standards-based mathematics education for students with EBD.

EBD research in academics is a relatively young field. The math investigations are still in their infancy. "Math research is twenty years behind reading research for children with disabilities, and work on academics with children with EBD is behind other areas," says Neel.

One reason for this is preconceptions: "Nobody thought they could do the math," says the UW researcher.

Can they? It's a complex but critical question as educators — who have long concentrated classroom efforts on getting students with EBD under control — are tasked with new academic demands.

Historically about half of students with EBD don't graduate, yet new federal laws mandate they be provided a comprehensive academic program. All students, including the special education students who represent about 12 percent of Washington State's school population, are to be brought up to standards in all subjects and undergo assessments that verify their grasp of those subjects.

For students with EBD who have traditionally been taught the most basic of "the basics," it means being tested on the kinds of mathematical understanding that in many cases they haven't been taught. "It's a cookie-cutter notion — that everyone is going to be an academically competent kid and demonstrate their competence in the same way," says Neel.

"Nobody thought they could do the math."

UW PROFESSOR RICHARD NEEL

Most students with EBD don't like tests. They may wad them up and toss them. Faced with the WASL, which demands that they not only come up with answers but explain them, many students with EBD freak, blow up, then bomb — even if they're given extra time and extra help. "The WASL makes them feel stupid, and they don't like that," says Neel.

Much of the recent educational legislation is designed to not make these students feel stupid, to respect the dignity and educability of each child. Under this mantle falls the Individuals with Disabilities Education Act, which requires that special populations, if possible, be mainstreamed into general education classes.

Can students with EBD be integrated? Should they? Neel can argue either side: "There is an assumption that these kids can be adequately served in general education classes, but the evidence is overwhelming that some can't. All are capable of learning; some, however, are just not capable of learning the way other students learn."

At this point only about one-third of students with EBD have been mainstreamed across the country.

Most are still in special education classes where the teaching of mathematics concentrates on highly structured lessons, constant feedback, short assignments, individual seatwork, and lots of correct answers and positive reinforcement. It's the kind of controlled situations that help keep behavior in check. "Before the No Child Left Behind Act, the focus was more on controlling their behaviors and improving their social skills. Less attention was paid to academic progress," says Neel.

These special education classrooms differ markedly from the inquiry-based classrooms advocated by math reformists, classrooms where students work in groups, tackle open-ended real-life problems and projects, argue mathematical ideas and explain their conclusions — reasoning processes tested in WASL items that require students explain their thinking. This means that many students with EBD face a dramatic mismatch between the math instruction they receive and the state tests they must take.

Further complicating their situation is the fact that most special education teachers have not been trained in math reform curricula, and don't know how to teach complex inquiry methods. Nor do many believe these methods belong in a classroom of students with EBD. "Special educators and researchers in the field of EBD do not recognize the changing nature of the goals of mathematics education in the 21st century," reports a 2006 investigation by Neel and Washington State University professor Hal Jackson.

The investigation, which looks at three Pacific Northwest school districts, showed that conceptually oriented instruction was essentially absent in six out of eight special education classrooms under study.

Where do the special education teachers begin making the sweeping changes needed to implement inquiry-based math in their tightly controlled classrooms? Will change set off students with EBD, who often function best with routine? Or can special education teachers — as well as general education teachers — help students with emotional and behavioral problems gradually learn to self-monitor their behavior, grasp complex directions, cooperate with their peers and articulate complex mathematical ideas?

It's an immense task, complicated by a number of factors. One is the difficulty in recruiting special education teachers in the first place. Recruiting special-ed teachers with sophisticated math skills is even more daunting.

Another factor is that, at a time when professional development in the field is critical, funds for special education are drying up as the government turns its attention to general education reform.

Despite the problematic picture, business-as-usual for students with EBD is no longer an option. Nor, argues Neel, should it be.

"If you get a child to behave in a classroom where everything is structured, where he gets constant feedback and has no frustration, where the workload is trivial and inconsequential, you might show progress. But it is false progress, because it has little to do with the real world."

First step, he says, is to teach students with EBD operational social skills. "If you're going to prepare kids to engage in an inquiry-based curriculum, you have to expose them to the structure of that classroom and the social interactions necessary to operate in that room. Otherwise, they flounder and fail."

For many students with EBD, this could be the best education they'll get in school — real social skills that prepare them to operate in the outside world, socially and academically.

"We now have No Child Left Behind academically," says Neel. "How about No Child Left Behind socially?"

FOR MORE INFORMATION ON NEEL'S OBSERVATIONS OF CLASSROOMS SEE:

Jackson, H. G., & Neel, R. S. (2006). Observing mathematics: Do students with EBD have access to standards-based mathematics instruction? *Education and Treatment of Children*, 29, 593-614.

A TEST FOR THE TEST

is WASL Math Fair for All?

Fairness is not a lofty academic idea; it is demanded by federal and state mandates that require equitable education for all students.

That means the tools used to measure the success of education — tools like the Washington Assessment of Student Learning, or WASL — must also be equitable.

It has been the job of UW professor Catherine Taylor, on special assignment to the Office of the Superintendent of Public Instruction as principal investigator for the WASL, to test the test, study different populations' responses to problems, and ensure that the test is fair to all students.

Her research has pointed to the need for WASL adaptations for special-education students, versions for the blind and, translations for English language learners. It has also uncovered surprising data on who benefits from traditional math testing.

The multiple-choice test questions, preferred in much math testing, seem straightforward. They typically have four answers. One is correct: A, B, C or D. The others are incorrect. But on the math portion of the WASL, the A, B, C, D items don't fairly assess certain groups of kids.

Taylor's research shows that, although males tend to perform well on multiple-choice questions, females do not. The test questions that are most effective for non-Asian minorities and females are conceptual math problems — open-ended items that may require students to draw graphs, create tables, write comparison statements, or show how they arrived at their solutions.

These "performance-based" questions offer partial credit for partial understanding and recognize that students may have unique ways of solving problems — ways that may have little to do with traditional algorithmic mathematics teaching. "There are many routes to the right answer in problem-solving. We always think when we write test questions that we know the reasons behind the answers kids choose. We don't," says Taylor, who had 10 years experience as a professional test developer before coming to the UW in 1991.

"The WASL is based on the idea that education is supposed to be for all students, not just the college-bound," says Taylor. "The kind of algorithmic math traditionally taught in middle and high school might make sense — with no further explanation — to future theoretical mathematicians, but it seems a fairly elitist thing to push algorithmic math as mathematics instruction for all students."

"Most kids are not going to become mathematicians, but they are still going to need to use mathematical ideas. What happens is that the largely abstract mathematics instruction becomes a turn-off for many students so they drop out of mathematics. We are one of the very few nations in the world where it's acceptable to say, 'I don't do math.'"

To ensure that every student has a chance to engage with mathematical thinking and use mathematics to solve problems, the WASL asks students to put mathematical procedures into action in ways that are useful in daily life. The test questions — all written by Washington State math educators — may require students to figure out which cell phone plan gives them the most calls for the least money, or what the length and cost of a fence for a given rectangular area would be.

About one-third of the math WASL items are performance-based.

"The goal is to make sure that all of these questions on the WASL are really about applications of math, not just abstract mathematics with little relevance for the students," says Taylor, whose studies show that when test questions are placed in more meaningful contexts, students are more likely to attempt them. "Students can't show what they know if they don't try to answer the test questions."

Washington State was one of the first states to incorporate performance-based questions along with multiple-choice questions on a state test, and their inclusion helped stoke the fires of back-to-basics discontent with the WASL. Why were students drawing and writing on a large-scale math test? What kind of test was this? If teachers were teaching to the test, what kinds of math instruction were Washington State students getting? Most importantly, why were so many students failing a test that could determine whether or not they graduate from high school?

"Most kids are not going to become mathematicians, but they are still going to need to use mathematical ideas."

UW ASSOCIATE PROFESSOR CATHERINE TAYLOR, principal investigator for the WASL

More than 25 percent of the class of 2008 have yet to pass the math portion of the WASL. Even with the inclusion of performance-based items, low-income and non-Asian minority students show significantly lower pass rates than their peers. It's a high-stakes test that churns students' stomachs, grates on their nerves, and, too often, angers their parents.

It's easy to blame the messenger. "If there is a measure that shows kids slipping through the cracks, that measure becomes very threatening," says Taylor. "It's like deciding to get rid of the thermometer because it shows people have a fever. And people in poverty have an even higher fever."

A place to look for change, she suggests, is not in the testing, but in the classroom. Many students in mathematics classes are still not being brought up to the modern content standards tested in the WASL — standards that require them to learn to think analytically and logically, and use experience and knowledge to solve problems. Taylor notes, "Research demonstrates significant improvement in WASL scores in schools that have adopted 'standards-based' curricula."

Why push for deeper mathematical understanding and problem solving? The answer is again equity. Historically, rote drill, memorized algorithms, and procedural step-by-step math instruction worked for top math students who needed few explanations, but left a segment of the student population flailing. Many dropped math at the first opportunity, then bombed on large-scale tests. "These kids, slowly over time, see an algorithmic test and think 'I'm too stupid for this. I won't even try,'" says Taylor

Under the federal No Child Left Behind act, that scenario is no longer acceptable.

"If we were still practicing medicine the way people did 100 years ago, the human race wouldn't be living as long as we are. Bacteria would be killing us daily," says Taylor. "So why would we think that mathematics instruction from the 19th century is what we still should be doing today?"

The debate over the WASL will continue as educators, administrators, politicians, and business leaders consider how best to educate a broad populace to perform mathematically in a new millennia. Meanwhile, WASL math scores continue on a slow rise. Almost 20 percent more 10th graders are passing the test on their first try than five years ago. At the 4th-grade level, almost three times as many students are passing. Taylor stated that, "Nationally, Washington State is one of the highest performing states on the National Assessment of Educational

A brief history of the WASL

UW professor Catherine Taylor provided technical support in the early days of WASL development and recalls that it was not initially meant as a high-stakes test. It was developed in the mid '90s as a grade-level assessment tool geared to newly adopted state standards. In 2002, federal mandates associated with the No Child Left Behind legislation demanded that states document higher across-the-board academic performance, and the WASL was repurposed.

State law mandated that, when WASL scores were deemed to be reliable and valid, the state's school board would tie passage of the WASL to high school graduation. Based on research conducted over the years, including research by Taylor, WASL scores passed the reliability and validity requirement, which made passing the test mandatory for graduation by 2008.

mid '90s

2002

Progress — and Washington State is one of very few states that is closing the achievement gap for African American students. Washington State is seeing real growth in mathematics achievement for the first time in many decades."

And, this time, the students who do not perform well on A, B, C, D multiple-choice problems are in the count. "It has been remarkable to see how the test is making it possible for students who have not done well with traditional assessments to show the things they have learned," says Taylor.

FOR MORE INFORMATION ON TAYLOR'S WORK WITH STATE ASSESSMENTS SEE:

Taylor, C. S. (2002). Incorporating classroom based assessments into large-scale assessment programs. In G. Tindall & T. Haladyna (Eds.), *Large Scale Assessment Programs for All Students*. Erlbaum.

FOR MORE INFORMATION ON THE RESEARCH BASE OF THE WASL SEE:

Taylor, C.S., Hirsch, T., & Cammaert, R. (2004). *2003 Grade 10 Technical Report for the Washington Assessment of Student Learning*. Olympia, WA: Office of the Superintendent of Public Instruction.

Recent legislation, however, changed the graduation mandate. To earn a Certificate of Academic Achievement, students must still pass reading, writing and mathematics WASL tests. However, they can graduate without a certificate if they continue to take mathematics courses beyond 10th grade and take an appropriate mathematics assessment.

In May 2007, Governor Chris Gregoire moved the date for passage of the WASL mathematics test to 2013. The move was designed to give the state time to retool how mathematics is taught and to train teachers to do it. The governor's reasoning: "It was simply unfair to hold our students accountable without holding our system accountable."

2008

2013

what we ca

Effective Mathematics Instruction

What can policymakers, educators and parents do to help students develop the mathematical skills they need in the 21st century? Our research suggests a number of ways to make a difference:

1 + 2 × 3 >

In conversations about alternative instructional approaches, begin with a concrete example of teaching an important concept, listen for common learning goals, and build from there.

Become familiar with state and national standards in mathematics and consider whether your students can meet them.

Support release time for teachers to allow them both to take part in on-going professional development and collectively make sense of the ideas and practices they learn for their particular schools and classrooms.

n do

4 ÷ 5 = !

Require that all students receive the support they need to benefit from mathematics instruction.

Ensure that students know when and why to apply mathematic procedures, not just how.

Contributing Faculty

ILANA HORN
Assistant Professor
Curriculum & Instruction

REED STEVENS
Associate Professor
Educational Psychology

ELHAM KAZEMI
Associate Professor
Curriculum & Instruction

CATHERINE S. TAYLOR
Associate Professor
Educational Psychology

RICHARD NEEL
Professor
Special Education

MARK WINDSCHITL
Associate Professor
Curriculum & Instruction

UW College of Education Faculty

Robert D. Abbott
James Soto Antony
James A. Banks
Nancy Beadie
Philip Bell
Virginia W. Berninger
John D. Bransford
Sharan Brown
Douglas A. Cheney
Marilyn Cohen
Frances Contreras
Michael Copland
Carol A. Davis
Eugene B. Edgar
John R. Frederiksen
Karin Frey
Chrysan Gallucci
Geneva Gay
Nathalie J. Gehrke
Margery Ginsberg
Allen D. Glenn
Leslie Rupert Herrenkohl
Meredith Honig

Ilana Horn
Roxanne Hudson
Shirley Hune
Brinda R. Jegatheesan
Joseph Jenkins
Diane Carlson Jones
Janine Jones
Gail Joseph
Elham Kazemi
Deborah Kerdeman
Donna H. Kerr
Stephen T. Kerr
Kathy Kimball
Alan J. Klockars
Michael S. Knapp
Min Li
Joe Lott
James J. Mazza
Deborah McCutchen
G. Williamson McDiarmid
Morva McDonald
Doris McEwen
Richard S. Neel

Maresi Nerad
Susan Bobbitt Nolen
Steven Olswang
Walter C. Parker
Charles A. Peck
Margaret L. Plecki
Bradley Portin
Susan Sandall
Ilene S. Schwartz
Roger Soder
Scott A. Stage
Reed Stevens
Tom Stritikus
Catherine S. Taylor
Edward Taylor
Sheila D. Valencia
Manka M. Varghese
Patricia A. Wasley
Elizabeth West
Joy Williamson
Mark A. Windschitl
William Zumeta

Directors of Affiliated Centers

Sheryl Burgstahler
Stephen Fink
Rosemary Sheffield

At the animal shelter there were 8 mother cats and each mother had 4 kittens. How many kittens altogether?

College of Education
University of Washington

Box 353600
Seattle, WA 98195
Phone: 206.616.4805
Fax: 206.685.1713
edudev@u.washington.edu
http://education.washington.edu

EDITOR: Deborah McCutchen
WRITER: Mary Lynn Lyke
COORDINATOR: Mairead Reinhard
PHOTOGRAPHY: Mel Curtis, Suzie Fitzhugh

UNIVERSITY OF WASHINGTON
Box 353600 • Seattle, WA 98195

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